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AUTHOR Papert, Seymour A.
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ABSTRACT

The paper describes the successful use of the LOGO System (an interactive graphics, computer based learning environment) with 12 severely physically handicapped adolescents with cerebral palsy. Five goals were set forth concerning the opportunity to work with microcomputers in interesting ways, the assessment of the students' spatial competence, consequences of lack of experience in language production, the LOGO system's potential human and social consequences, and the need to document this impact for dissemination. The LOGO classroom setup is described as are activities undertaken, including business programing using mathematics, work on spatial deficits, remedial writing, and diagnostic efforts using graphics and seriation tasks. It is explained that the system also allowed for visual experience of shapes and spatial configurations. The system is said to have resulted in significant improvement in the sense of personal worth. (CL)

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INFORMATION PROSTHETICS FOR THE HANDICAPPED

FINAL REPORT

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January 1981

Seymour A. Papert, Principal Investigator

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1. SUMMARY

We describe the successful use of a novel regime for severely physically handicapped but mentally alert cerebral palsy adolescents, involving activities which are user-initiated and predominantly spatial and geometrical in nature, and consisting of an interactive graphics, computer-based learning environment called LOGO. The LOGO system contains a set of powerful graphics primitives, a text-editor, and full list-processing capabilities for performing non-numerical problem-solving tasks. Examples of **programming, math and problem-solving activities** are given, as well as ways in which LOGO is of special interest to those who work with the physically handicapped, e.g.,

a. as a source of **spatial manipulatory activities** to address the lack of such manipulatory experience in the lives of these motorically restricted individuals. The relevant experience provided by the regime consists of the manipulation of screen "objects" using minimal motor effort, and the system is used both as a **diagnostic tool**, where deficits in spatial understanding can be explored using the coarsest of movements (thus skirting the notoriously difficult problem of doing performance tests in motorically restricted individuals); and as **therapeutic tool**, where an intrinsic interest in the computer-based activities themselves provides an intense motivation to perform these spatial tasks. This performance, almost as a side-effect, can lead to an improvement in fine motor control.

b. as a medium for **generating text**, using text-editing facilities, for those whose motor control of a writing implement has been affected adversely. This activity, again, can be used in diagnostic mode, to establish patterns of expressive language disability, or, in suitable patients, as a remedial tool for language re-education. We have found the creative writing efforts of some of our subjects quite unexpectedly illuminating.

c. as a way for a motorically restricted intellectual to keep **notes in the form of computer files**, to engage in problemsolving at a high level without having to do it all in the head, by using the **computer as a scratchpad**; and by having access to everything that computer networks enable --- access to data-banks, to the activities of fellow-programmers and so on.

The resulting dramatic **improvement in sense of personal worth** and the consequences for intellectual activity has led the school to implement its own computer center using the recently implemented APPLE LOGO system. **An extension of the standard LOGO system allows the use of screen versions of assessment tasks.** We have found deficits in spatial reasoning in some cerebral palsied subjects, using tasks involving ordering by length, shape recognition, spatial localization and mental rotation. Combining information from a variety of such LOGO activities provides a powerful way of making fine-grain analyses of performance in spatial, numerical and writing domains; these provide the basis of **remedial programs** which focus on the revealed deficits and so allow directed and effective intervention which is already showing substantial results.

The potential for **increased vocational access** as a result of the increased possibilities for intellectual activity are discussed, and a **dissemination plan** for potential users based on the implementation on low cost personal computers now available is presented.

2. INTRODUCTION

2.1 What we undertook to do

In the proposal that generated the work being reported here, we outlined a technological step toward the realization of *Information Prosthetics*, with a focus on using rather than making the technology involved. What is needed, we argued, is to give handicapped individuals the facility to have interesting, exciting and creative things to communicate about. We proposed to invite physically handicapped individuals to share in the revolutionary opportunities created by the advent of the personal computer; and suggested that such an opportunity for sophisticated intellectual activity be provided in the context of a computer-based learning environment-- a LOGO classroom -- whose main features are a concentration of initiative and control in the hands of the user, and a flexible and open-ended, yet structured environment based on an interactive graphics system for doing computer programming, mathematics, animation, music, physics, and for creative writing using a text editor. Proceeding from this educational base, we had particular theoretical issues in mind, viz.:

what was the consequence of the lack of motoric experience, which characterizes the lives of cerebral palsy victims, on their spatial understanding?
could we use computer for AS-IF spatial manipulatory experience, both as a therapeutic and as a diagnostic tool?
what could our findings in this regard tell us about "normal" development?

In this report, we describe how handicapped students at a school in Boston (the Cotting School for Handicapped Children) did some of these things, what they and we learned and are learning in the process, and how the school has taken over a part of the experiment. Some of the several possibilities for further work are raised.

2.2 Participants

Students

After an initial lecture-demonstration, attended by the entire staff of the Cotting School, followed by a consultation involving the Superintendent, the administrative officer and the head of the math-science department, it was decided to work intensively with Ma. (see Appendix 1), who is the most severely handicapped student in the school, a 17- year old quadriplegic with athetosis and severe dysarthria. Later we worked less intensively with 4 more senior students, with 3 students in the middle school; and with 3 students aged 7 years at the Kennedy Hospital School.

The characteristics of these 11 pupils are given in Appendix I.

Personnel

The research team at MIT was lead by Seymour Papert and Sylvia Weir.
Jose Valente, Gary Drescher, Linda Laatsch, and, for a while, Steve Philips, were research assistants involved in teaching, programming, and in the administration of tests.
The Cotting School personnel whose co-operation made the study possible, includes
James Petros, Teacher / Director. Mathematics - Electronics Dept.;
Michael Talbot, Assistant Superintendent, and until recently, Director, Resource Room;
and William Carmichael, Superintendent.

2.3 Goals of the Study

Goal One

The LOGO system is designed to be flexible enough to serve as a vehicle for many different patterns of learning. Since the first goal of our experiment was to extend to physically handicapped students an opportunity to work with micro-computers in interesting ways, we wished to know how such students would respond to the LOGO activities (see chapter three) developed for non-handicapped individuals. So the general objectives we have formulated for non-handicapped students become our objectives in this study, viz., to provide an environment in which students will learn to feel comfortable with the computer; learn the elements of the LOGO computer language; learn the subject matter of TURTLE GEOMETRY; to become familiar with the use of a text editor; and to develop and exhibit problem solving skills.

Using the material accumulated in a detailed study of sixteen students in the Brookline school system (Papert et al., 1979), we proposed to undertake a comparative learning study which, in addition to documenting the story of physically handicapped children learning to program, and the way LOGO activities can be integrated into the rest of the curriculum, would consider theoretical issues such as the relation between learning to program and learning in other areas, and the relation between learning and differences in cognitive styles. Integral to achieving this set of goals in the case of the physically handicapped student is the question of what *modifications* would be required to the existing system to cater for the special needs of the handicapped population. We hoped to show that existing prostheses could be used to greater effect in a LOGO learning environment, providing as it does the possibility for interesting and challenging activities, with a concomitant increase in motivation. An important step would involve the use of simple devices for reducing the number of gestures required. As we moved to more handicapped individuals, we envisioned the need for harnessing more radical technological aids. In particular, we proposed to explore the use of an eye-tracking device.

The *significance* of achieving this goal would be an improvement in basic skills, and raising the intellectual ceiling to which such students can aspire and add to their choice of vocational outlets.

We present our findings on the abovementioned in Chapter four.

Goal Two

Our second goal concerned the study of the spatial competence of our subjects. The reasons for our emphasis on spatial manipulatory experience are as follows:

To the extent that sensori-motor activity contributes to the full development of the cognitive structures underlying spatial understanding, individuals with severe motoric restrictions suffer from a reduced opportunity for such learning. Hence they are at risk in regard to the development of a *deficit in spatial competence* as a result of the restricted manipulatory experience available to them. Since severely handicapped persons cannot engage in the motor activities which ordinarily support the acquisition of cognitive structures, what is missing from their lives is the explicit confrontation between the actions they perform and the consequences of such actions in the physical world, an experience taken for granted in normal development. Such a confrontation can be made possible in a computer-based interactive graphics learning environment which provides the opportunity for complex manipulation of visual objects on a screen. We call these manipulations AS-IF actions (see

Papert and Weir, 1978) and suggest that a rich source of such activities can be found in the LOGO system, developed over the past decade at M.I.T. for use with elementary and secondary school children.

In addition to the manipulatory experience we could provide with LOGO, we proposed an extension of the existing LOGO system so as to be able to replicate standard assessment tasks by creating *graphics screen versions* of such tasks. For example, we would implement AS-IF Piagetian tasks, which would then enable us to test activities such as carrying out a SERIATION task, hitherto testable in severely motorically restricted persons only in a multiple-choice form, which precludes an examination of the processes involved in carrying out the relevant maneuvers. What we were pointing to, then was the possibility of using our system, suitably extended, as a *diagnostic tool* for use with this population.

The *significance* of this aspect of the work could be far-reaching; providing evidence one way or another as to possible cognitive consequences of motor disability gets to the heart of current concerns in Cognitive Science. There is a theoretical as well as a practical educational interest in exploring the texture of the cognitive abilities and the patterns of disruption, displayed by persons with such unusual experiences. Is there a delay or a deviation in, or an absence of, development of specific capabilities? Are there dissociations which might yield insights into theories of brain function? For example, do individuals in this population exhibit systematic patterns of spared and impaired competencies for different areas of mental activity, e.g. linguistic, spatial, deductive, which could provide evidence for the specificity/generality issue; i.e. to what extent is a particular type of computational process specific to a given faculty, and to what extent do common mechanisms support different areas of cognitive functioning.

We present our findings in this area in Chapter five.

Goal Three

Our third goal related to linguistic aspects of the physical handicap, and was directed toward a study of the consequences of lack of experience in language production. What would be the effect of providing a language prosthetic for such people, in the form of an experience of using a text editor and text filing system? We had in mind the possibility of working with non-vocal victims of Cerebral Palsy, and were interested in both the question of the acquisition of an understanding in the absence of production, and in the possibility of learning occurring in the context of computer-based linguistic activity. In the event, we encountered a lack of experience in the production of *written language* which generated a rich source of issues which are described in Chapter five.

Goal Four

This goal concerned socio-affective issues. Aside from the educational impact of the LOGO experience, attention is drawn to its potential human and social consequences. It is characteristic of the LOGO system to seek to promote a close association between a child's cognitive development and an environment where he or she takes the active role in his or her learning. This aspect becomes especially important in work with special needs children, for example, in the work with an autistic child (Weir & Emanuel, 1976); with the learning-disabled child (Weir & Watt, 1980) and, most poignantly, with the Cerebral Palsy child, where a particularly debilitating consequence of the gross physical handicap is the dependent, passive role it imposes on its victims. A profound

lesson has to be learned, one which is taken for granted in "normal" development. *A handicapped individual has to learn to believe that an action he takes can have an effect on his environment.* The uncompromising way in which LOGO places initiative and control in the hands of the user and gives the user a chance to know what she knows, means that she may now engage in sustained, independent activity and be her own critic. The resulting enjoyment and sense of personal fulfillment can greatly enhance their general sense of personal worth and competence and could have important effects on the members of this disadvantaged section of society, not the least of which is the creation of a high degree of motivation which can then form the basis for significant learning in formal subjects.

Evidence of this effect is presented in Chapter six.

Goal Five

As the study proceeded and the size of the impact we were having on the school became clear, **a fifth goal emerged, viz., the need to document this impact for purposes of dissemination.** A major interest of ours concerns the dissemination of the information and expertise generated by this study so as to put these to practical use. Steps in a utilization plan are presented in chapter 9.

3. THE LOGO LEARNING ENVIRONMENT

3.1 The Idea behind the Activity

In a computer implementation of Dewey and Montessori methods, we provide a context for learning by doing by linking up various devices to a computer so that a child can, via a computer, "command" an output device to carry out an action, a miniature communication system.

The LOGO system reverses the usual relationships which appertain in computer instruction. Whereas in a conventional computer assisted instruction situation, we have a clever program teaching a "dumb" student, in the LOGO system, the student is required to teach this dumb computer how to carry out a task. This engenders a respect for accuracy, since the literal computer cannot understand nearly-correct instructions, as humans do. *To teach a task one really has to understand that task. The learner is seen as a model- builder and the program as a model of the task, and understanding can grow in the process of constructing that program.*

Programming in an interactive computer graphics situation lends itself to an emphasis on *process* rather than on *product*, in that the typical tasks are structured to enable direct feedback on the intermediate steps during the solving of a problem. A discrepancy between what is intended and what actually happens is thus more readily available to both teacher and learner than is usually the case, and such an error or "bug" becomes a source of insight into the learning process, rather than something to be ashamed of or angry about.

In short, problem-solving experience is built in to the daily activity in a very direct way, such that the student can become an "embryo scientist", making hypotheses about likely outcomes of one or other course of action, testing these ideas, and refining the hypotheses in the light of experience

The development of the LOGO language has been accompanied by the invention of domains in which to formulate problem tasks to be solved by the learner programmer. The best known of these is TURTLE GEOMETRY. The output device connected to the computer is either a mechanical "turtle" or a cursor on a graphics screen, capable of moving forward or backward in a particular direction relative to itself and of rotating about its central axis. As the student commands the turtle to move around, intuitive body knowledge about his own moving around in space is mobilized, providing an intuitive and qualitative formalism for a range of mathematical ideas, from the idea of angle and regular polygon, up through concepts underlying differential geometry and many classes of differential equations, including the equations of motion of Newtonian physics. In this way, considerable fragments of classical mathematics and physics can be imparted to the user, both in terms of formal understanding, and equally important, by giving an intuitive "feel" for phenomena.

Progressively more complex programming concepts are mastered, using the full list-processing capabilities of the LOGO language. Examples of programming, math and problem-solving skills involved include:

acquiring a sense of issuing a command and getting the desired effect on the computer;
the notion of a procedure as a entity which can be constructed, named, and then become part of a hierarchy of procedures;
using repeat, recursion and looping;
using variables in procedures and the beginnings of Algebra;
representing and manipulating knowledge as non-numerical lists as well as other more traditional data-structures such as arrays;
a number as a thing which does work for you, an appreciation of orders of magnitude, estimation of distance and rotation, circles and curvature, coordinate systems, both intrinsic and extrinsic and the beginnings of formal geometry and trigonometry;
the relationship of the structural hierarchy of procedures to problem-solving strategies such as top-down planning and the idea of modular programs.

It is worth remarking that LOGO as a programming language provides a more effective way than does a language like BASIC for doing computer-based science just because it invites the use of hierarchies of user-defined procedures which correspond to the structure of the problem. This allows for a clearer conceptualization and for more intelligible programs than the less transparent code produced by free use of GOTO statements in a language such as BASIC.

In the process of inputting their programs and in deciphering the computer messages, all students doing LOGO develop skills in *reading, spelling and typing*. The availability of a text-editor enhances this experience and provides both motivation -- the delight of getting "clean copy" -- and a practical tool, allowing some students to make dramatic progress in creative expression. Examples of activities include:

Programming projects, e.g., writing a sentence generator program, which picks items from lists of verbs, nouns, adjectives, etc., in a prescribed order, and generates "funny" sentences; and refining this program to take note of gender and number concordance, and the like.
The file-handling and text-editing facilities can be used to generate text, e.g., a notebook of events; a group newspaper containing letters, stories, jokes, quizzes and the like, and **allows students who may have never before written anything whatsoever to produce their first piece of writing without the intervention of an adult.**

Since career access is enhanced by an ability to express oneself linguistically, e.g., a scientist needs to be able to generate reports, the opportunity to develop a facility in the use of a text-editor, especially for those whose motor control of a writing implement has been affected adversely, is of

crucial importance. The system can be used in *diagnostic* mode, to establish patterns of expressive language disability, and, where required, as a *remedial* tool for language re-education (see section 4.2).

3.2 The LOGO classroom

A LOGO classroom was set up in a room forming part of the electronics and math area in the Cotting school. The hardware consisted of three LSI 11 - based 3500 systems, two purchased by the grant and one rented. Each 3500 system has separate text and graphics screens, and a disc handler for floppy disc storage. A DECwriter III, also purchased on the grant, was connected to the 3500 system to enable the production of hard copy. A plotter, provided by the home laboratory, was used to generate copies of LOGO drawings.

A special input device, a *Button box*, has been used to introduce students to their LOGO work. The principle here is to reduce the number of gestures required for any particular input. This is achieved by having fewer keys than the conventional keyboard, and having these keys larger and further apart from each other. Each larger key, called a BUTTON, can stand for an arbitrarily long string of alphanumerics, typically a LOGO command, for example: FD 10 can be executed by pressing the button labelled FD.

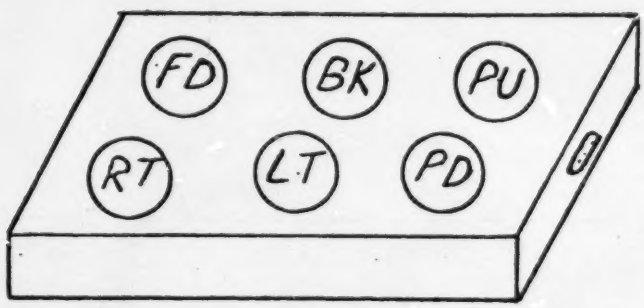


Figure 1

New commands can be added in a modular fashion by hooking up new boxes of buttons. A simple version of this device was used by Perlman (1972) with 3 to 5 years old children and by Weir and Emanuel (1976) with an autistic child. This same economy of gesture can be achieved by making software changes, and relabelling the keys on a regular keyboard according to their new function.

The students received two half-hour sessions a week, and were able to use the machines on their own at other times. An estimate of how much time was spent by each student is given in Appendix 1.

3.3 Data Collection

This consisted in:

the recording of detailed observations of the students' activity by members of the research team;
the reactions of the school personnel to the impact of the project on their students;
the use of computer and video-recording of the performance of subjects on a number of assessment tasks under development;
and the generation of annotated "dribble files".

A dribble file is an automatic stroke-by-stroke record of all the work done on the computer by a particular student; automatic recording in this way can be initiated at the start of each lesson. At the end of each lesson, the dribble file is printed out and annotated to form a hard copy record of programming activity, together with significant interactions with teachers and other students. This record formed the basis of the analysis of LOGO activities. Another use of an automated "dribble" file arises in connection with the graphics screen tasks (see section 5.3).

4. LOGO AND CEREBRAL PALSY

4.1 General Findings

Our experience over the past two years at the Cotting School leaves little doubt that the computer-based LOGO activities we have designed have had a considerable impact on the children with whom we have worked; and that the answer to the question of the viability of LOGO activity as part of a school curriculum for Cerebral Palsy students is a resounding "yes". Detailed profiles of the children we have worked with will be published separately. Here we give some of the highlights.

The range of LOGO activities in which our handicapped students have engaged covers a much wider spectrum than has previously been encountered in non-handicapped populations. More than ever, each child is a law unto himself. Progress is invariably slow. One obvious reason concerns the physical handicap. All the children with whom we have worked can type, albeit slowly and by dint of a variety of ingenious props. The DELETE key is invaluable since they do hit unintended keys. We used the button-box for the 11-14 yr-olds, both for pedagogic reasons -- beginning LOGO is easier when each push of a button results in a single action -- and as a way of speeding things up for those students whose slow typing makes learning anything at all too difficult. However, there are advantages in living with the slowness when the subject wishes to be in as "normal" a setting as possible, and when the actual exercising of the affected hands and fingers results in unexpected improvements in fine motor control. Given that the subjects we used all had the minimum motor facility required by our input devices, the use of the eye-movement apparatus described in the proposal has so far not been necessary.

The use of the computer as a notebook-cum-scratchpad of ideas has replaced the need for "doing it all in the head" and has given a new lease to the intellectual life of these students. This can be summarized as the experience of *sustained* problem solving in learning to program, in the various parts of math which form a large part of LOGO activities and in the generating of their own notes. This experience is often the first in which the students have been observed in the *process of tackling problems where they are required to initiate solutions, try them out, decide when to change track and when to persist, respond to feedback* -- all those things tend not to happen in the usual dependent, adult-dominated situations which characterize their lives. The sheer fact of this whole new world of

knowledge and of their own independent management of this, has had a profound effect. One subject has spent 6-9 hours a week at the computer since the onset of the project; has been brought to the LOGO laboratory weekly during vacations when the computer at the school is not available to him; lies in bed solving LOGO problems in his head, and has changed his career plans as a result of this experience.

The youngest group is also the most profoundly handicapped group we have worked with, and progress is indeed very, very slow. Two of these (one mute quadriplegic; one non-cooperating dysarthric quadriplegic, both presenting problems of assessment of intellectual ability) had rather intrusive emotional problems and our attention was almost wholly taken up with these. The third was a charming, cooperative verbally fluent boy whose very limited counting skills and marked perceptual problems made the twenty sessions we had with him yield a lot of rather poignant excitement on his part, but rivetingly slow progress in acquiring LOGO primitives. It would seem that except for the isolated case, such profoundly handicapped individuals should not be worked with at present.

4.2 Details of Activities

General: Programming and Mathematics

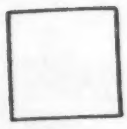
A wide range of projects were undertaken, examples of which are given in the case studies. The older the group the more obvious is the connection with other aspects of the curriculum. We detail this for Algebra and Trigonometry in Appendix 2. What is required now is a systematic attempt to integrate these activities into the school curriculum.

Problems in *business programming* suggested by the manager of the printing shop (a commercial venture which handles outside orders) have generated interesting programming tasks. Examples include estimating the cost of orders, which involved writing routines for truncating and rounding off decimal numbers (not supplied as system routines in LOGO) and hence an exploration of the way numbers are represented in the machine; and developing an algorithm for choosing the size of stock paper appropriate to a given order so as to minimize wastage.

Focal Remedial activities: Spatial Deficits

In the case of the 11-14 year olds, a significant incidence of spatial deficit, as demonstrated by the diagnostic tasks, see chapter 5, was reflected in the difficulties experienced in doing LOGO. Projects undertaken by this group generated insights into the difficulties. An example is the "Christmas Tree" project, carried out by Ja., a 13-year old quadriplegic, (see Appendix 1), with very good linguistic skills, but extremely poor spatial ability.

Ja's favorite project was the production of a newspaper, in which he showed his ability to plan his activity. He first generated the section headings, and then went back to fill in details, taking section headings and expanding them, beginning with the easiest and not with the first -- a lovely example of top-down planning. In contrast, his spatial ability was very poor; e.g., he could not seriate (see section 5.4), and his LOGO work was elementary. In order to maintain his interest, a series of procedures were provided for him to produce a Christmas tree (figure 2a), and his task was to assemble the parts and to decorate the tree. He had himself written the star procedure, and, using the ball procedure with different inputs, he produced figure 2b. His program instructions, given alongside the figure, show his peculiar choice of numbers. The point we make is that his response to the need to generate numbers was to invoke the successor function, rather than some appropriate estimate of distance, on the basis of which he would choose the number he needed to use in the LOGO commands.

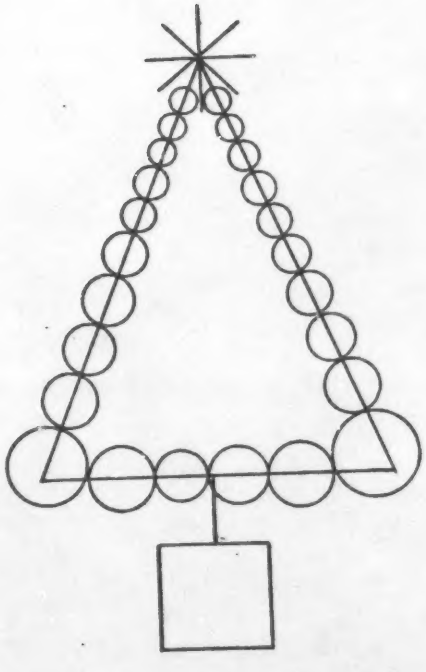


SUPPORT

TREE

BALL :X

Figure 2a

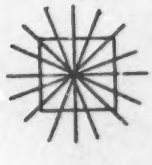


```
BALL  9
FD    10
BALL  11
HT
ST
FD 12
BALL  13
FD    14
```

Figure 2b

Initial Position of the Missile

FD 120 Moves the Missile into the Target



Target Explodes as a Reward

Figure 2c

In response to this inability to estimate distance, and/ or the failure to exercise this ability, we instituted a remedial program. This consisted of several versions of a target game, in which he was required to estimate the number needed to move the missile to the target -- a hit was rewarded with an explosion, (figure 2c). We are beginning to see an improvement in his estimating skills, and will be looking for evidence of transfer to other areas.

Focal Remedial: Writing

If severely handicapped individuals are to hold down a job, the quality of their writing is important. For many of these students, this is the first opportunity to generate their own text, without the intervention of an adult. We show such a sample of writing produced by Ma., the quadriplegic cerebral palsied student mentioned above.

> "I ment Dr. Sileva Where, Jose Valente and Gary Drescher on October 5, 1978 at 9 : 32 : 47 AM. which the compuer I was so excized it like being it a waitting & maternace room at a hospiltal whiting to fine if oot's a boy or a grail.
> We had a and we whont you to do it fist for us I am LOGO number "1" ginny pig. When they get a new idse they say to hel, michalel we had a and we whont you to do it fist for us
> like a nice guy I do if I wont to or not. I do and then I give my por and con on the idse. I tell them why I came up for a allturative. Why you mite ask? Becose I know how the person on the arther end feel. Becose I am the middle man betwee M.I.T. and handcap people.
> I also teach five stundts. No tow lean at rate. Some ask then I know they are intered in leaning about logo. Then the one that take for granted. I can tell.
> When I teach I lean form my standt. as well or bedter then form a book. I call that on the job training.
> My fist and every day experreance with the compuer when it cash and it lost but it keep on losting all that I have tort it but keep no teaching it overy and overy agian when I bring back to live."

This writing is of quite surprisingly low quality for a 17- year old whose programming achievements had confirmed his high intelligence. The question arises as to how much this is due to lack of experience or to damage to the relevant brain area. Are the errors random, resulting from inaccurate typing, thinking faster than he is able to type, lack of spelling experience, and the like? Or is there evidence for particular patterns seen in patients with known lesions, e.g. the type of disturbance associated with a lesion in the anterior portion of the dominant hemisphere (Broca's expressive aphasia) produces a different pattern of language disorganization than does a lesion in the posterior portion of the dominant hemisphere (Wernicke's fluent aphasia). In the former, there is a "disturbance of the mechanisms that subserve the ability to structure a string of words syntactically" (Caramazza and Berndt, 1978), e.g., inflectional markers for plurals, possessives, and third person singular /s/ are affected differentially. As yet we do not have sufficient data for a detailed analysis of this sort. However, we list some of the types of errors which occur in the above passage.

We can see errors with tense markers:

"feel" (feels); "handicap" (handicapped); "take" (takes); "cash" (crashed); "keep" (kept).

However, these errors could conceivably be due to his misperception of the spoken words, upon which he is basing his spelling (notice "fine" instead of "find"). The latter possibility could cover the instances of letter omissions which occur, especially "r" before a consonant, which is not sounded:

"fist" (first); "lean" (learn).

Either haste and/or lack of experience, or brain lesion, could conceivably account for the numerous omission of words:

it [was] like being in; we had a [idea]; No tow lean at [same] rate.

and the reversal of letter order:

"grail" (girl); "idse" (idea); "por" (pro); "stundts" (students); "tow" (two); "form" (from); "no" (on).

In order to investigate and treat this problem we have set up a *focal remedial program*. All his English lessons take place in the computer room, using the text editor, instead of a scribe whose activities were masking the true situation. He writes his own book reviews, essays and the like, on the computer; in addition, and, in collaboration with his English teacher, we have instituted a series of remedial writing sessions involving specific exercises based on weaknesses shown in his writing, in order to assess how much improvement we can achieve. Early indications are that a great deal of improvement can be achieved.

5. DIAGNOSTIC ACTIVITIES

5.1 General

Since severely handicapped persons cannot engage in the motor activities which ordinarily support the acquisition of cognitive structures, what is missing from their lives, as described above, is the explicit confrontation between the actions they perform and the consequences of such actions in the physical world, an experience taken for granted in normal development. Such a confrontation can be made possible in a computer-based interactive graphics learning environment which provides the opportunity for complex manipulation of visual objects on a screen. We call these manipulations AS-IF actions (see Papert and Weir, 1978) and suggested that a particular virtue of the the LOGO system would be the possibility of using the standard LOGO activities which have a large spatial component as a way of providing *remedial* therapy for this gap in experience. Now we turn another possible use, viz., as a *diagnostic tool*.

Notice how placing motorically deprived individuals in an interactive graphics situation generates a significantly novel way of assessing such persons, in that the very element viz. motor handicap whose restrictions leads one to suspect the presence of a deficit in spatial cognition, renders the ascertainment of that deficit very difficult. Performance tests are notoriously difficult to administer to this group. Our world of AS-IF actions gives us the possibility of carrying out selected, standardized AS-IF manipulative tasks on individuals with severe motor handicap, which we hoped might add to our understanding of these issues. We have been engaged in developing a way of doing this.

Before proceeding to describe our findings we briefly review the relevant literature.

5.2 The Evidence for Spatial Deficit in Cerebral Palsy

We are particularly interested in stressing the extent to which motor components of the tasks administered affect the performance of motorically restricted individuals on those tasks.

1. Impaired figure-background discrimination in Cerebral Palsy subjects has been reported using masked and embedded figure tasks presented as a tactile task (Dolphin and Cruickshank 1952) or as a visual-perceptual task (Dolphin and Cruickshank(1951); Cobrinik(1959)). Cobrinik notes that handicapped and non handicapped groups perform about equally well on the simpler items, but that Cerebral Palsy children perform less adequately as the items become more difficult. Scrutiny of the tasks suggests that the increase in complexity amounts to a gradual increase in the puzzle or problem solving nature of the task. The tactual figure-ground discrimination task (Dolphin and Cruickshank 1952) mentioned above involved exploring a surface with the hands and making a drawing of what had been perceived. That is to say there is a large motor component in this task.

2. Cerebral Palsy subjects perform better on perceptual discrimination (recognition) tasks (of simple geometric forms) than they do on perceptual analysis tasks (finding which of several figures the presented fragment was part of); and on perceptual synthesis tasks (which of several sets of lines could be used to construct a given figure), as shown by Birch and Lefford (1964).

3. Cerebral palsy children perform badly on the Goodenough draw-a-man test, commonly interpreted as evidence for their poor body image. However, they perform equally badly when the task involves copying very simple figures, suggesting a difficulty of drawing generally, (Abercrombie and Tyson 1966).

4. Measures of visual perception in Cerebral Palsy yield scores progressively lower as the motor component of the test used increases (Zeitschel et al 1979).

5. Cerebral palsy children who fail on the block-design reproduction task of the WISC, can succeed, most of the time, on a task which requires them to choose the one correct design out of three presented block designs (Bortner and Birch 1962).

6. Particularly relevant is the exploration by Wedell and his colleagues (1972) of the relationship between the amount of independent mobility experienced and the development of size constancy. The task requires subjects to match the height of an adjustable rod with standard rods at increasing distances away, and shows that under both monocular and binocular conditions of vision, children with the longest independent mobility (over 1 year) achieve a higher degree of size constancy at the greater distances than children with less experience of walking. This is not correlated with age at testing.

This support for the thesis that lack of experience is the prime factor in the development of these spatial deficits is complemented by the experimental work of Held and Hein (1963), in which two groups of kittens were exposed to the same visual environment, one group "actively" by walking through it, and the other "passively" by being carried through it in a basket, supports a determining role of motor activity in the development of visual perception in kittens. The analogy with severe physical handicap is compelling. A well-known supporter of this line of thought is Piaget, who assigns a central developmental role to sensorimotor activity in the development of spatial concepts in children (see for example Piaget, 1952). The results of Bower (1979) and others showing evidence for the very early, neonatal presence of some of these spatial notions suggests that the story is more complicated than that. Interesting in this connection is the result of Decarie, who showed normal development of size constancy in thalidimide children with phocomelia (1968).

But a moment's reflection reveals a profound ambiguity in the finding of a spatial deficit in these subjects. While there has undoubtedly been a restriction in motor activity, there has also undoubtedly

been brain damage, and although motor dysfunction is the predominant, defining characteristic of this group, the various etiological agents of cerebral palsy do not as a rule recognize functional boundaries; a pure motor disorder is rare. In particular, the original insult, be it vascular, mechanical, infectious or whatever, can affect those areas in the brain which recent research has shown to be concerned with spatial understanding (reviewed in Denckla et al. 1980). And so, in any particular case, the spatial deficit in question may have resulted either from *direct* damage to the neural substrate which supports such activity in the undamaged brain, or *indirectly* from damage to motor areas, the dysfunctional consequences of which, namely, restricted manipulatory experience, have led to the spatial defect under consideration.

Wedell et al (1972) consider that they have disarmed the possibility that their result reflects differences in degree of underlying brain damage, corresponding to degree of mobility restriction, by showing no covariance of size constancy judgements with performance on a vocabulary test. Similarly, Cobrinik (1959) concluded that location of damage was not relevant to figure-ground discrimination deficit. This would no longer seem to be a warranted conclusion in the light of a decade of work on hemispheric specialization. An excellent summary of current views on the specialization of the right hemisphere for spatial understanding is given by Denckla (1980).

We take the view that it is always necessary to consider both the lack of experience and the brain-damage components in allocating a causal role for any demonstrated deficit.

There are then two issues of interest here. First, can we use our tasks to demonstrate spatial deficits in such a way as to allow a detailed demonstration of the components of the deficit? Second how can we proceed to clarify the causal antecedents of such a deficits. In this report, we show that the first question can be answered in the affirmative. In the concluding section of the report, we describe an experiment we hope to carry out to illuminate the second issue.

5.3 Graphics Screen Tasks

Our objective is to replicate standard assessment tasks such as a Piagetian SERIATION task, hitherto testable in severely motorically restricted persons only in a multiple-choice form, which precludes an examination of the processes involved in carrying out the relevent maneuvers.

A substantial programming effort has produced an efficient general purpose system for implementing a wide variety of tasks. New tasks can be added with relative ease. Features of the system include the provision of an automated record of the moves made by the subject complete with a time marker; and a facility for using this record to drive a rerun of the task for purposes of analysis.

The system consists of a collection of buttons including four which move the cursor around, two for rotation, and GRASP, DROP and PEEK buttons as described below. Several tasks have been implemented and work is in progress to test their use with handicapped and non-handicapped children.

We have chosen tasks which allow scrutiny of steps in the process of spatial problem-solving, rather than merely a display of the choice of among end products. We make no claim as to the reliabity of these tests. The work is in too preliminary a stage for that to be possible at present.

5.4 Seriation

One of the tasks we have used is a 2D version of Piaget's (1952) SERIATION task in which a cluster of randomly oriented "sticks" are required to be "carried", using a cursor, and arranged in serial order along a "table-top". Before performing this screen version, subjects were asked to do the standard Piagetian task with wooden sticks, the "real" task. To eliminate the problem of fatigue, we used only four sticks for each version of the task. If the subject was unable to carry out the task, a three stick version was used. If the four stick task could be successfully carried out, additional sticks were presented for insertion into the seriated row.

For the graphics screen task, we allow the subject to become familiar with the buttons, using a two-stick display. To move a particular stick, the subject must direct the cursor, called "hand", using the four directional buttons (in a northerly, southerly, easterly, or westerly direction), until the "hand" touches the stick. At this point, pushing the GRASP button causes the stick to be "grasped" by the "hand". Now pushing the directional buttons moves both the "hand" and the stick; pressing a rotational button can rotate the stick clock or counterwise. When the stick has been moved to the desired position it can be dropped by pressing the DROP button. After this practice session, the test proper is carried out.

Results

We have tested 35 non-handicapped children, of between 4 to 9 years of age, and 16 physically handicapped, aged 11 through 18 years, on this task.
All non-handicapped children age 7 years or older could perform both the "real" and the "screen" tasks. Children between 4 and 6 have problems with this task, as described by Piaget.
All these younger children find the screen task more difficult than the real task. In contrast, all handicapped children tested found the screen task easier than the real task.
Eight of the sixteen (handicapped) could not seriate. All except one subject of those who could seriate could insert extra sticks correctly, in both versions of the task.

> The exception was 13-yr old Ja. (already mentioned in section 4.2) who could do the screen seriation task but not the insertion step of that task; and could NOT seriate real sticks. It seems that the enormous effort of performing the real task left him without enough processing power to tackle the seriation problem, *although he knew that what he was producing was not correct.*

An analysis of the stages of performing the task, to be published separately, shows that there is a difference in the extent to which subjects select sticks to be placed in order by size, versus selecting by proximity or randomly. There is an interaction between the presence of handicap and the medium of the test ,i.e., using graphics screen or real sticks. Non-handicapped children tend to select real sticks in order of size, and screen sticks not in order of size, thus subsequent correction of the line of sticks has to be made in the latter case; whereas handicapped subjects seem better able to select by size in the screen task than with the real sticks (see figure 3).

This supports the view that the effort of the motor task rather than the conceptual problem is what is being measured in the real task.
Examples of the end result are given in figure 4.

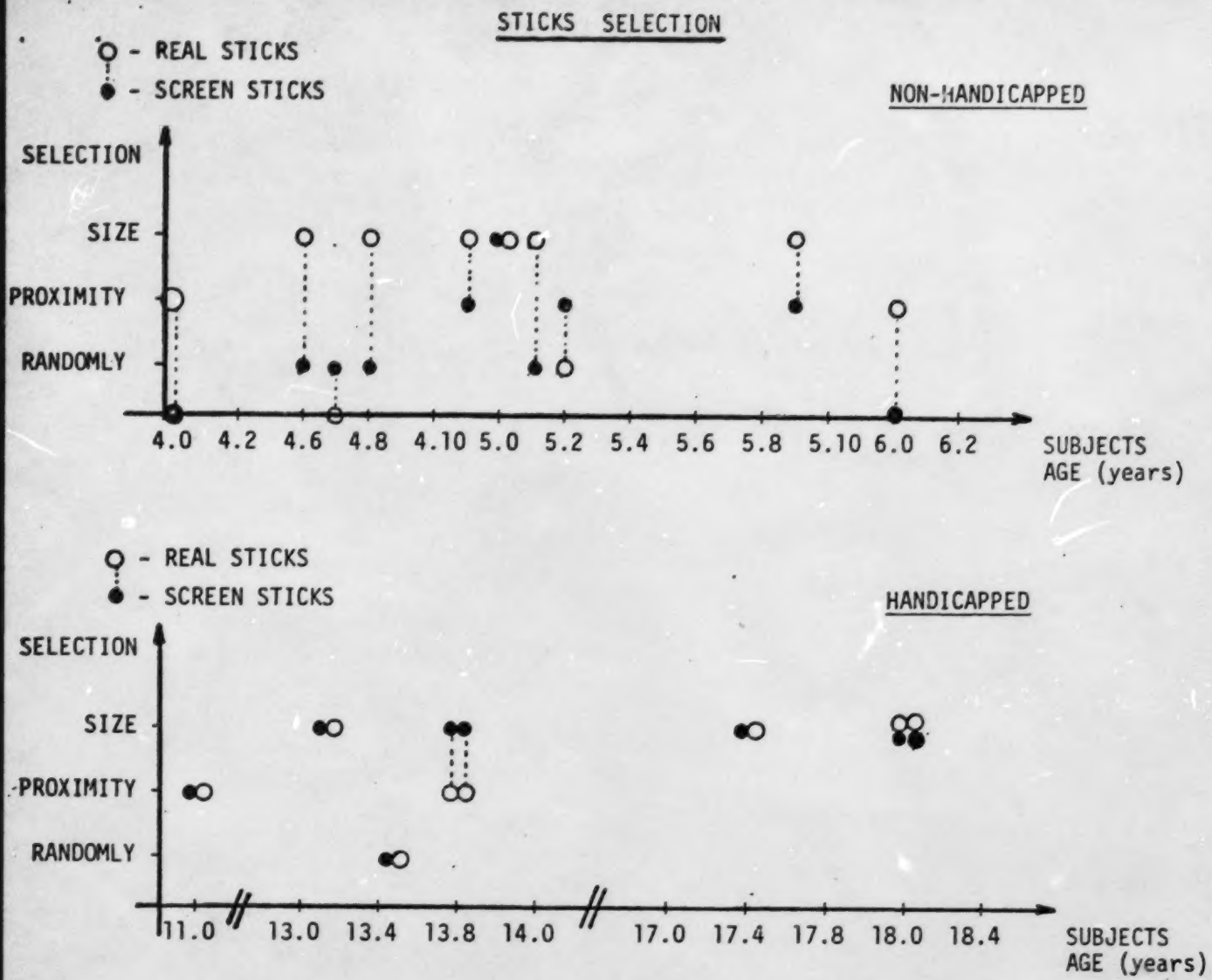
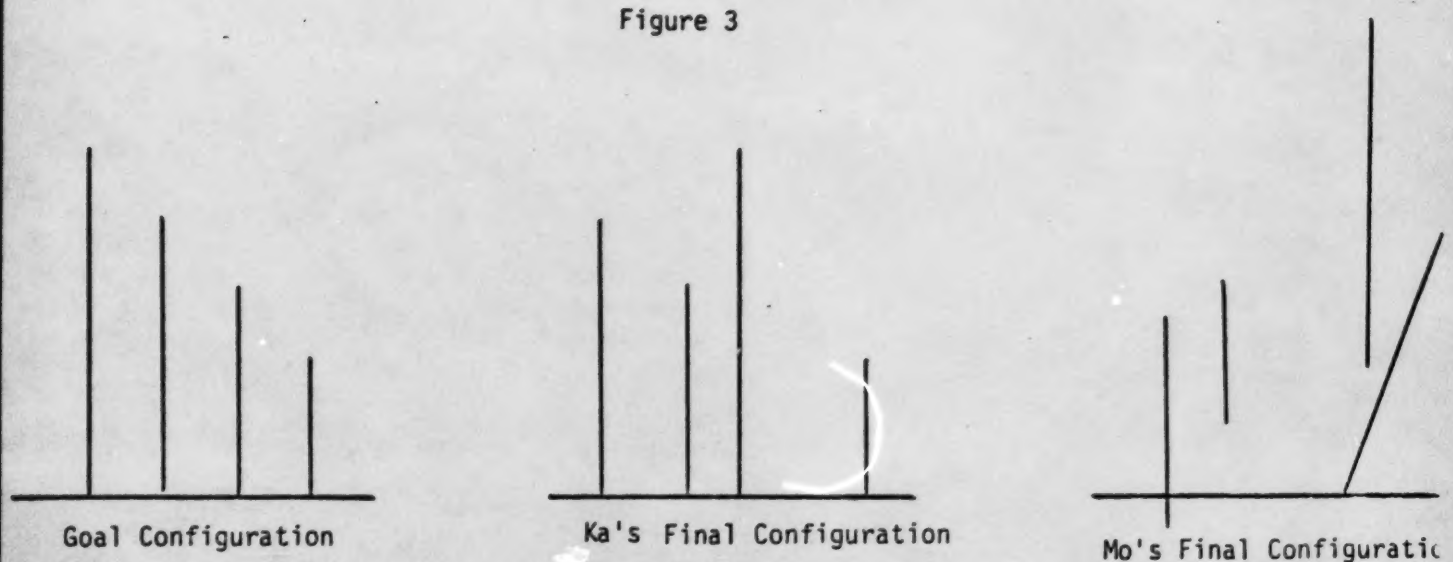


Figure 3



EXAMPLES OF SCREEN SERIATION

Figure 4

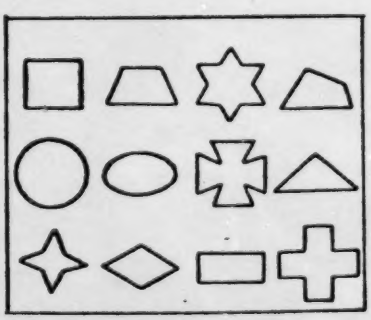
5.5 Pseudo palpation

Severely physically handicapped persons can enjoy the visual experience of shapes and spatial configurations to a much greater extent, usually, than they can indulge in the manipulation of objects in space. This latter manipulation involves a coordination of tactile information with proprioceptive information generated as the hands and fingers move with and over the objects, and with data from the motor component i.e. the coordinated instructions to muscle groups which correspond to particular movements. Haptic identification of objects develops more slowly than visual identification, and has been shown to be significantly impaired in brain damaged children (Rudel et al.,1974). A possible explanation for this is the fact that the various features of the palpated object are not available "all-at-once" as they are in the visual case. They have to be searched for and integrated over time.

In an effort to replicate at least this last attribute, and because the standard palpation task clearly requires supplementing and modification for use in our population, we have invented a task we call "pseudopalpation". The game is to find a hidden figure on the screen by moving around a cursor which takes two forms, one when it is inside the boundary of the figure, and another when it is outside. The edge of the figure is detected by noting the change in shape of the cursor, and a small piece of the edge just crossed can be inspected by pushing the appropriate button. This allows the subject to accumulate evidence as to whether edges are curved, straight, horizontal, oblique, pointed and so on. Exploration of edge shape at different parts of the hidden figure can lead to a recognition of the hidden shape.

The same set of directional buttons are used for moving the cursor around in this task as were used in the seriation task. In addition, there is a button which allows the user to take a PEEK at the configuration of the edge which has just been crossed.

The set of possible shapes was taken from Laurendeau and Pinard (1970), who used wooden versions of these shapes to investigate haptic perception in 2-12 year-olds. A board displaying the 12 shapes, as in figure 5, was available for scrutiny during performance of the task. Seven of these were chosen as the test figures, viz. square, triangle, trapezoid, circle, maltese cross, diamond, and 4-star, and presented in that order.



Results

We have tested 30 non-handicapped children to give us data on which to base a grading of performance, and have developed a way of quantifying the behavior observed. In addition to using the tally of numbers of correct answers, we use details of the subject's strategy of problem-solving.

Our current algorithm takes account of features such as:
entertaining alternative hypotheses about what the figure can be,
searching for particular disambiguating features,
contour following or systematic exploration of extent of figure.

We have tested 9 handicapped subjects, aged 11 to 18 years, on this task, all of whom had an extraordinary amount of difficulty in performing it. Their individual scores are shown in figure 6 as open circles; 16 non-handicapped students (4 at each age from 9 through 12 years) were tested and the mean scores per year are shown as black circles in figure 6.

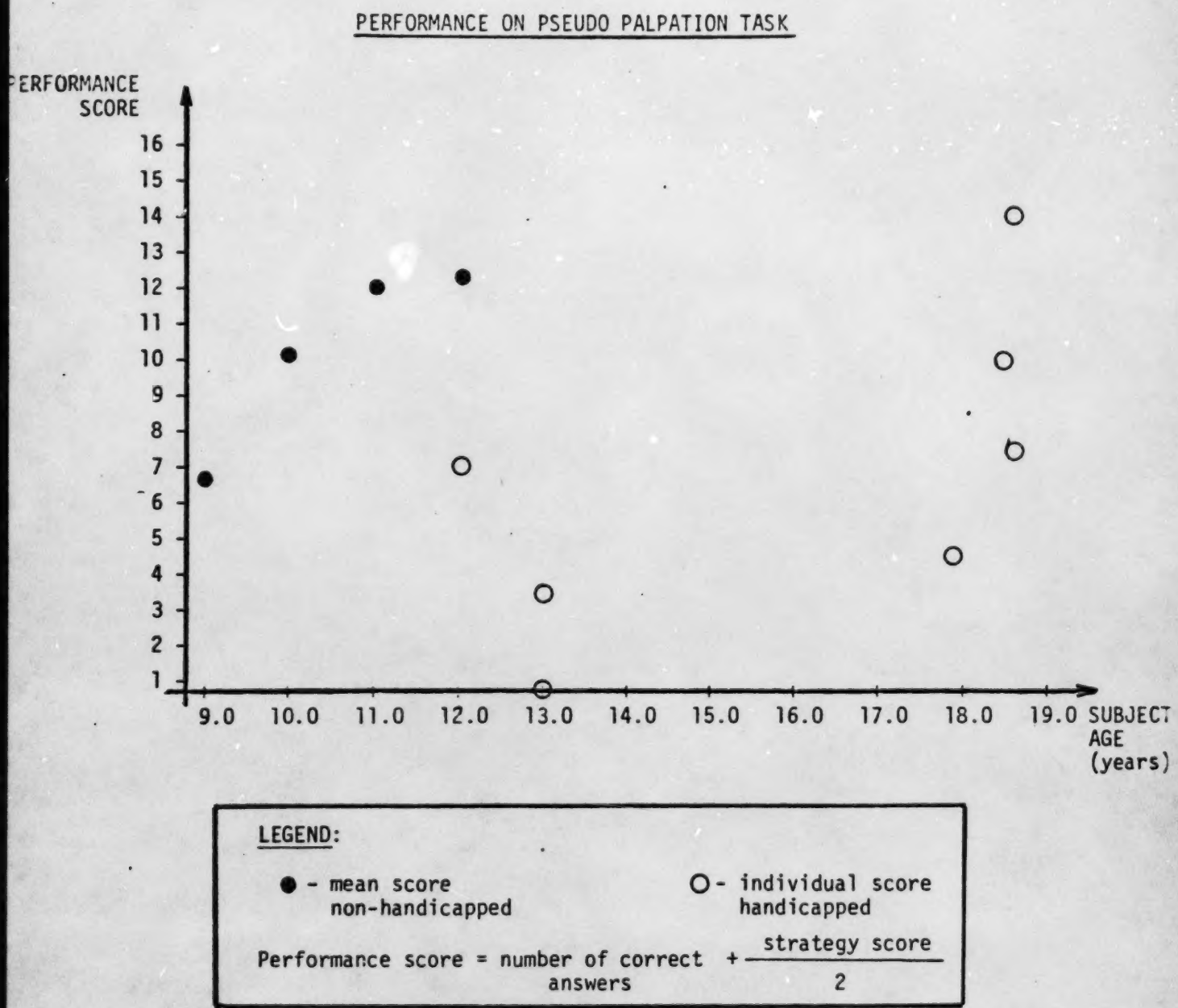


Figure 6

Preliminary scrutiny of the performance of Cerebral Palsy individuals shows a deficit in level of achievement on both dimensions i.e. number of correct answers, and age appropriate strategies used.

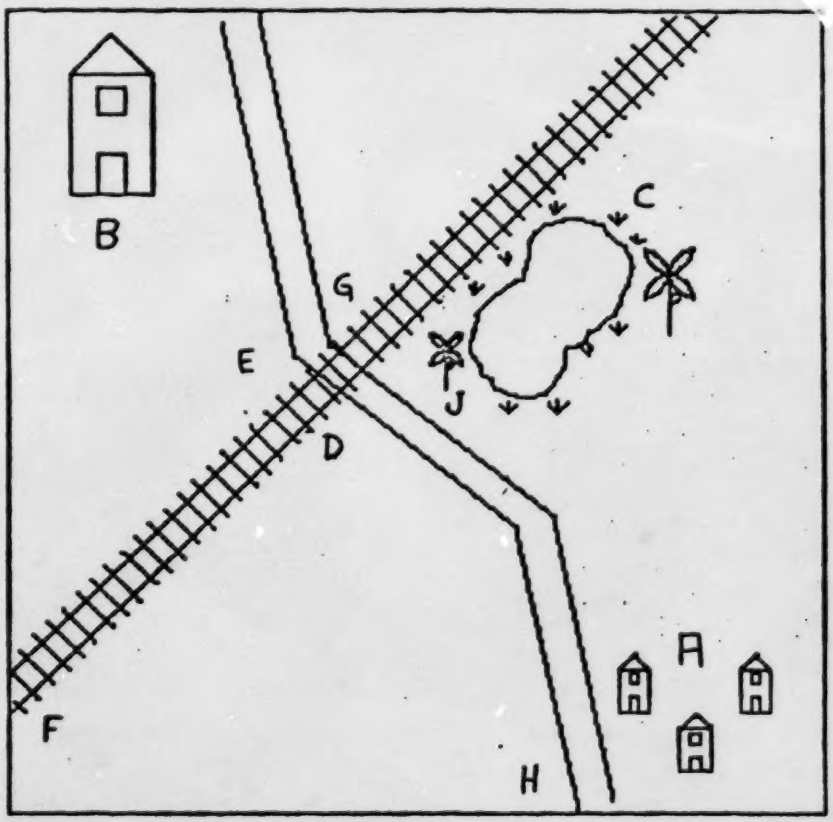
This task turned out to be a difficult one for the physically handicapped, as we surmised. The 11 - 14 year-olds appeared to be using a strategy which we were tempted to call "guessing" -- possibly more accurately labelled as "unknown" or "not clear to us". The 17-18 year-olds tended to match only on the fragment immediately under consideration, rather than on the basis of all previously seen fragments. Our speculation is that the lack of experience has somehow delayed the development of the facility to set up appropriate datastructures onto which incoming information of shape outline can be attached.

What will be of great interest, therefore, will be the effect of spatial problem-solving experience, as for example that provided by LOGO activity, on the level of performance of this group on this task.

5.6 Piaget's Village Task

Next we explored the performance of our subjects on Piaget's "village" (topographical) task (Laurendeau and Pinard, 1970) in which the child imitates on his drawing of a scene, the position of a doll on the experimenter's drawing, identical but rotated 180 degrees. Our task has two parts, the first of which is done with physical models of the scene, and the second of which has the child's scene drawn on the screen, with the cursor as doll. As in the screen tasks described above, the cursor can be moved around the screen (scene) by pressing appropriately labelled buttons on the console.

Nine positions of the doll, A through J, were used as shown in figure 7, these locations varying in their difficulty of description, i.e., in terms of proximity to particular objects such that the description accurately localizes them.



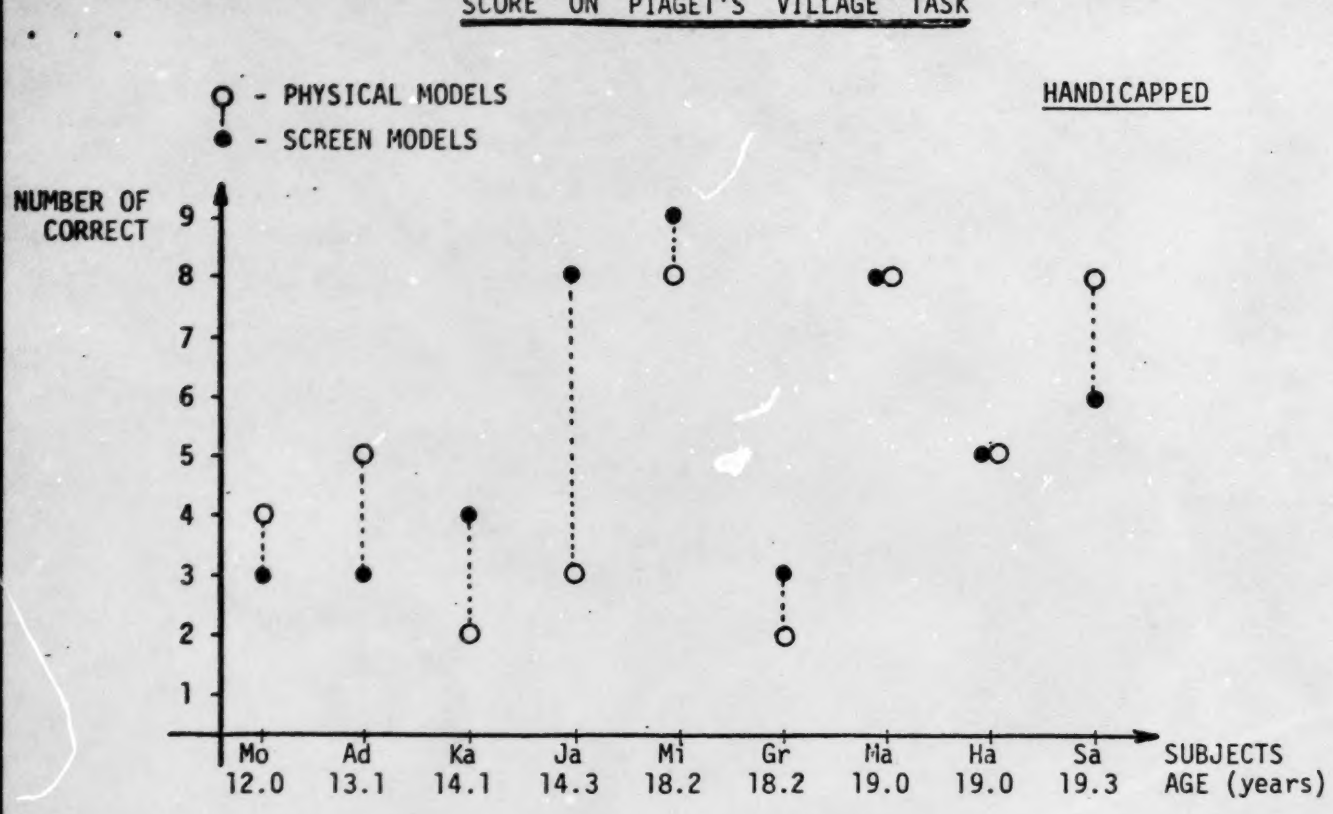


Figure 8a

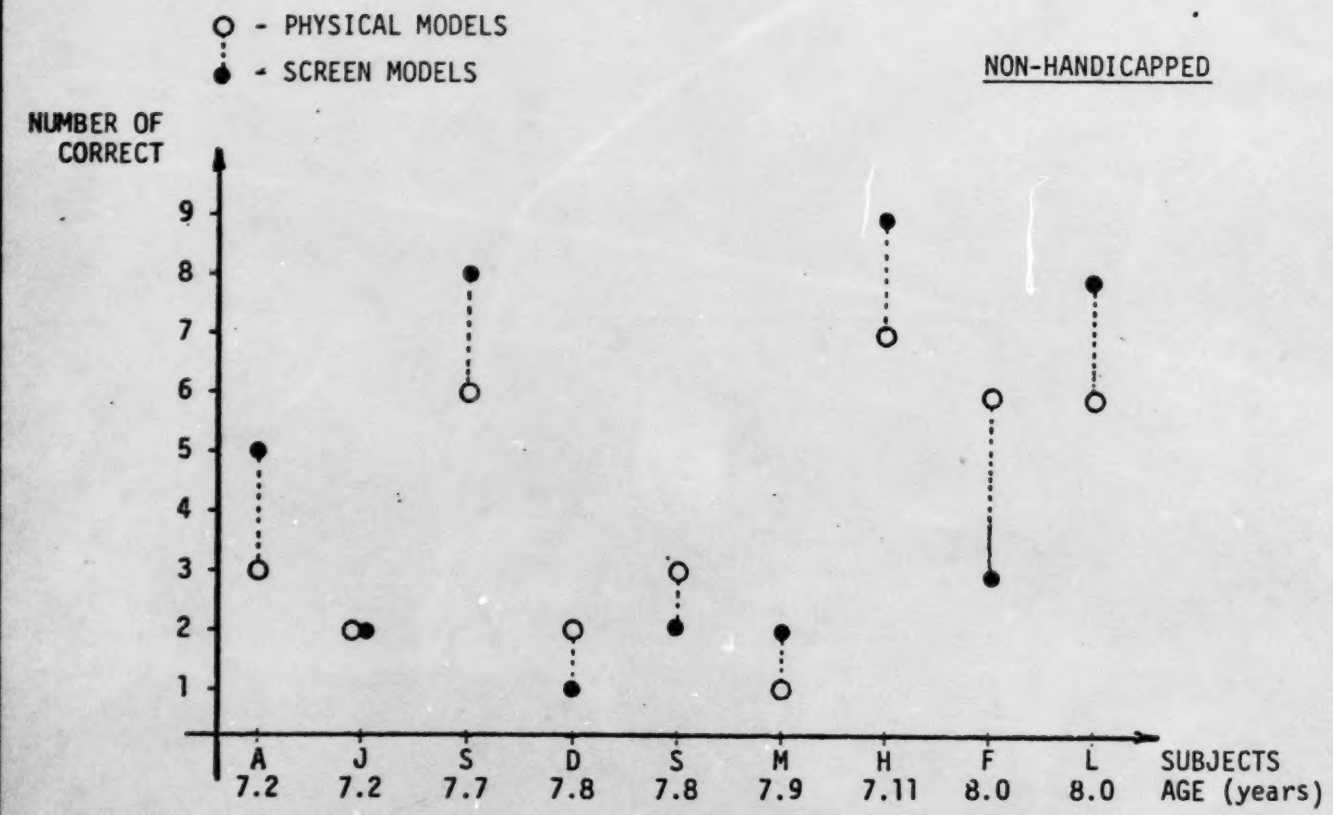


Figure 8b

We have tested 9 physically handicapped subjects aged 11 through 18. Their performance is shown in figure 8a, as the number of correct placements of the doll/ cursor on the 180 degree rotated test diagram. The performance of 9 non-handicapped 7-8 year olds is shown in figure 8b.

Here again we see a marked deficit in performance among the physically handicapped. An interesting example of the complexity of the processes involved, and thus in the assessment of the significance of this finding, is revealed by the performance of Ja, mentioned before, whose strategy in the "real" task was to copy the physical movement of the experimenter, thus getting the wrong placements, (score 3/9); whereas in the computer task he began describing the position of the doll in words and achieved a score of 8/9 correct placements. This subject has very good linguistic skills and very poor spatial skills, and succeeded in turning the computer version of the task into a linguistic task.

Our speculation is that, to the extent that the performance of this task hinges on the manipulation of datastructures, the absence of appropriate facility in handling "spatial" datastructures, supposing these are domain specific (e.g., arrays), could be responsible for the poor performance. Further, this task lends itself to solution using verbal descriptions only, and this switch of strategies seems to be facilitated by the presentation on a graphics screen, for reasons which are not clear.

A more direct assessment of the ability to handle rotated objects, (so-called mental rotation task) is the basis of an experiment by a MS student attached to our project. This task involves a judgement as to whether, in sets of pairs of figures, the two figures, one rotated with respect to the other, are the same or different. We are working with a screen version of Marmor's test for this ability, (Marmor, 1975). Ratcliff (1979) has shown an impairment in the ability to perform this task in adults with right hemisphere lesions.

Preliminary results show that the same 11-14 year old handicapped subjects who could not do the seriation and the village tasks cannot perform to criterion on the preliminary training part of this task.

6. SOCIO-AFFECTIVE ISSUES

The uncompromising way in which LOGO places initiative and control in the hands of the user and gives the user a chance *to know when he or she knows in any particular task,* represents a major feature of the system, and has a profound impact on students with special needs. It provides a high degree of motivation which then forms the basis for significant learning in formal subjects, providing a striking example of cognitive affective interdependence; i.e., user-based initiative generates motivation -- when you have to find out something in order to achieve some goal you have set yourself, your motivation is high and you're likely to go after it.

Furthermore, the sheer computer prestige effect seems likely to play a role in the results achieved; and the nature of the activities, where one can get a large and dramatic effect on a graphics screen can make one feel important. Probably the most important thing of all is the unusual, for the physically handicapped, experience of having an action one takes have an effect on the environment.

An intimation of the dramatic effects which can take place is provided by the Superintendent of the Cotting School at which our pilot LOGO program was run; an extract of his letter to us is reproduced in Appendix 3.

There is much evidence of increased motivation among the participants, as reflected in an intense competition for the use of machines, coming in an hour before school and skipping half the lunch break to work on the computer, and the frequency of animated discussion about various computer projects.

The versatility of the system supports a wide range of cognitive styles and levels of ability, (Papert et al., 1979), allowing a student to carve out an area in which he feels comfortable - a microworld - in which to work. The teacher can aim for a balance between working with strengths and exercizing weaknesses.

Individual case studies contain descriptions of the range of reactions to the introduction to LOGO, preferred activities of different students, differences in styles of debugging, styles of working, amount of risk-taking, response to the anxiety of a new subject and so on. As an illustrative example, we quote the subject who handled the devastation of failure by denial. Ja. was always ready to change his purpose to fit his latest error. It was a great step forward when he learned to tolerate making an error and allowed himself to benefit from the process of debugging that error. This happened while he was doing the Christmas Tree project, described in section 4.2 . Another subject, aged seventeen, was so uncertain, shy and lacking in self-confidence that she had the reputation of making no intellectual progress whatsoever. The virtues of LOGO applied particularly to her, and she has moved from a totally dependent situation, where she made no move on her own, and looked for reassurance after each command she typed, to one in which she works on her own for long periods of time and initiates her own projects which have become quite sophisticated.

7. CONCLUSIONS

We have described the successful use of the LOGO system with severely physically handicapped but mentally alert cerebral palsy adolescents. Examples of **programming, math and problem-solving activities** which were undertaken have been given, as well as illustrations of ways in which LOGO is of special interest to those who work with the physically handicapped. It can provide a source of spatial manipulatory activities; can be used as a **diagnostic tool**, where deficits in spatial understanding can be explored using the coarsest of movements (thus skirting round the notoriously difficult problem of doing performance tests in motorically restricted individuals); and can function as **a therapeutic tool**, where an intrinsic interest in the computer-based activities themselves provides an intense motivation to perform these spatial tasks. This performance, almost as a side-effect, has in some cases led to an improvement in fine motor control.

The system has acted as a medium for **generating text**, using text-editing facilities, for those whose motor control of a writing implement has been affected adversely. This activity, again, can be used in diagnostic mode, to establish patterns of expressive language disability, or, in suitable patients, as a remedial tool for language re-education. We have found the creative writing efforts of some of our subjects quite unexpectedly illuminating.

We have used the LOGO system as a way for a motorically restricted intellectual to keep **notes in the form of computer files**, to engage in problemsolving at a high level without having to do it all in the head, by using the **computer as a scratchpad**; and by having access to everything that computer networks enable --- access to data-banks, to the activities of fellow-intellectuals and so on.

The resulting dramatic **improvement in sense of personal worth** and the consequences for

intellectual activity has led the school to implement its own computer center using the recently implemented APPLE LOGO system.

We have demonstrated a potential for the use of screen versions of assessment tasks, the importance of which has only begun to emerge. The combined use of LOGO activities and the screen assessment tasks has given us a powerful way of making fine-grain analyses of performance in the domains of spatial, numerical and writing, allowing us to illuminate the nature of specific defects, which the school staff sees as greatly superior to the methods currently available to them. Together we are evolving remedial programs, tailored to these findings.

The result of this focussed remedial work has been the speeding up of learning in areas which had been previously regarded as incapable of improvement. The theoretical implications of this are equally dramatic, viz., that a portion of the deficits observed are likely to respond to intervention, i.e., are attributable to a developmental delay. The crucial point of the matter is to have a good analysis of what is the status of a particular ability or lack thereof, in order to be able to engage in directed and effective intervention.

Given that we have a delay in development of spatial ability associated with both brain damage and a lack of particular types of life experience, further work is required to sort out the underlying processes.

8. PROPOSED FURTHER WORK

a. Since the sheer control of a complex system by the Cerebral Palsy individual is useful in its own right, we need to consider the following kind of question: Does some of the improvement result nonspecifically from teacher attention and "computer prestige"? Alternatively, in the light of the predominantly geometrical character of LOGO activities, do the gains include a specific improvement in spatial competence, resulting from this geometric content?

What is required, then, is to provide a more systematic demonstration of the usefulness of LOGO-based therapy for Cerebral Palsy victims; and to delineate the causes for observed improvement or its lack.

It is expected that different subgroups of children will benefit to differing degrees from exposure to the regime proposed. It is essential that this differential benefit be accurately determined so as not to raise false hopes among the handicapped victims and their parents. A possible outcome of this aspect of the study would be a contribution to the development of a functional subcategorization of cerebral palsy. This presupposes the possibility of deriving characteristic profiles of "those who improve" and "those who don't", such profiles to be constructed from a combination of all the clinical data available on our subjects, and the results of our observations and tests. A preliminary form of validation would be to test the predictive power of such a taxonomy on further subjects. Such a taxonomy based on the nature of a handicapped person's response to an exposure to the LOGO environment could have interesting correlations with other classifications of this heterogeneous clinical entity.

A research design has been developed and we are seeking funds to carry out this study.

b. A second area deserving attention is the need to improve the bandwidth of communication available to the physically handicapped. The subjects we have worked with so far have been able to use a standard keyboard as input device, albeit with some difficulty, and this activity has produced an improvement in their fine motor control. However, there is a need to alleviate the difficulty in typing experienced, both by using specially constructed keyboards and by improving the transmission of what is typed; e.g. to signal the deletion of a mistype by part of the body other than the hand; and to use the existing technology of spelling correcting programs to circumvent the need for continually retyping all such errors. The aim here would be to increase the rate at which information can be transmitted by our handicapped subjects, by creating a more sophisticated flexible computer system than we have at present. This would involve both software and hardware modifications.

Again, we are seeking funds to carry out this work.

9. UTILIZATION PLAN

A major interest of ours concerns the steps necessary to promote the utilization of the information and expertise generated by this study, and how to put these to practical use.

We have made a selfconscious effort to involve the teachers and the parents of the handicapped students in an integral way in the program in order to ensure that the activity would not end with the research grant. As a result of the dramatic effect we have had on their students, the school at which we are working shares our enthusiasm about the potential of LOGO for the education of handicapped students. The enthusiasm has taken a practical shape in the form of a fund-raising campaign for the setting up of a computer center in the school. With the installation of three Apple II micro-computers, computer classes have commenced as part of the regular school curriculum.

As a first step in the our plan for the dissemination of these activities into schools for the handicapped, we are carefully *documenting* this process of introducing LOGO classroom activities into the school. We have instituted regular meetings with the teachers participating in the project to address relevant administrative, technical, and pedagogical issues. Given the innovative nature of the proposed regime, extensive documentation of all aspects of running such a system, including close attention to possible problems, is an essential requirement in order that this potentially beneficial activity can move from the schools in direct contact with the research group out into general usage.

We have applied for funding of a proposal which will generate such documentation, including the production of videotaped materials.

A second step is to conduct teacher workshops and lecture-demonstrations at institutions for the handicapped. In this way, we will spread awareness of the potential benefits of this activity, and obtain essential feedback from those out in the field as to the acceptability of our ideas, suggestions for improvements in our current arrangements, and the like. We are at present conducting weekly workshops for four teachers at the Cotting school and six teachers at the Massachusetts Hospital School,; in the case of the latter, the idea is that the teachers will determine the process of introducing LOGO into their school using the Cotting experience as a model. Again, given the innovative and interdisciplinary nature of the enterprise, *such a two-way dialogue is necessary*, and the outcome of this interaction will be incorporated in the materials described above.

Thirdly, we are participating in planning for the hardware and software requirements of a large scale spread of LOGO-based activities in this population. We are particularly well placed to do this, since all the development work for the LOGO system has been done in our laboratory. A version of LOGO has been implemented on the Texas Instruments home computer, and is operational in a private school in Dallas. A version of the LOGO system on the Apple II computer is currently being tested in a dozen localities all over the country. For all of this work, we will have access to the considerable fund of expertise, together with the use of facilities, both in our own LOGO laboratory, and in the Artificial Intelligence laboratory, of which the LOGO lab is a part.

Our laboratory is actively engaged in discussions with various publishers with a view to setting up a distribution mechanism for LOGO materials.

The advent of the relatively cheap personal computer has made it possible for even the smallest school and for many private families to acquire computers. It is essential that as many interesting, innovative, and pedagogically sound computer-based activities be made available to this very large population of users as possible, and that we ensure that the physically handicapped do not get left behind in this process. There is a need to consider policy decisions about the robustness, flexibility, and the maintenance of the systems to be adopted by the schools, and the special issue in relation to the handicapped of *what modifications are required to provide for their particular needs.*

All of the educational institutions and individuals concerned with the provision of the educational needs of the handicapped could be potential users of the results. A recent visitor from the Massachussetts Hospital School described herself as "feeling like a sponge, ready to soak up all you can tell us. We're all getting these little machines, and we can see their potential, but we don't know quite what to do with them." In the past there has been resistance to the introduction of the computer into their classroom by many teachers. Some of this may have been due to the impractical, expensive nature of what was available; some to the admittedly retrogressive nature of some of the drill-and-practice Computer Assisted Instruction packages put out. Neither of these objections pertains to our case. However, there remains the fear of the machine, which is not inconsiderable. Our impression is that this has become much less true recently, and that in particular, teachers of the handicapped are very ready to use all aids they can lay their hands on. In addition, there is more familiarity with the use of electronic devices in this section of the teaching profession, since the spread of electronic communicators. There is a large education need, in order to equip teachers with the expertise they will require to use the systems being developed, and this is why we have built teacher

Finally, it is necessary to foster the generation of an awareness in industry of the need to make available opportunities for handicapped individuals to enter careers in computer programming and other science areas, based on a familiarity with the use of micro computers. The ultimate goal of all of the above is to allow the physically handicapped person to enter into the life of the community as an independent agent, as far as this can be achieved. Increasing basic skills in reasoning, in mathematics, in problem-solving, and in understanding spatial concepts all have their reward in enabling the fulfillment of the individual, only in as much as they help that individual to attain productive self-sufficiency. It is therefore of the utmost importance to lay the foundation for readily available vocational access.

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10. APPENDICES

Appendix 1

Characteristics of subjects

Name	Date of birth	Clinical features	Duration of LOGO experience
1. Carol (Ca)	February '71	Severe Cerebral Palsy Quadriplegia, left side more affected than right Non-vocal Wheelchair	3 months 40 minutes per week
2. Jeffrey (Je)	February '71	Severe Cerebral Palsy Quadriplegia Wheelchair Perceptual problems	3 months 40 minutes per week
3. Audrey (Au)	September '70	Severe Cerebral Palsy Quadriplegia, right side more affected than left dysarthric Severe emotional disturbance	3 months 40 minutes per week
4. Mona (Mo)	September '68	Severe Cerebral Palsy Quadriplegia, right side more affected than left Wheelchair	Nil
5. Adele (Ad)	August '67	Moderate Cerebral Palsy Quadriparesis, right side more affected than left	1 year 4 months 1-1.5 hours per week
6. Kate (Ka)	August '66	Moderate Cerebral Palsy Paraplegia Crutches Perceptual problems	1 year 6 months 1-1.5 hours per week

7. James (Ja)	January '66	Severe Cerebral Palsy Hydrocephalus and Prematurity Quadriplegia, left side more affected than right Wheelchair Perceptual problems	1 year 6 months 1-1.5 hours per week
8. Milton (Mi)	July '62	Moderate Cerebral Palsy Paraplegia Crutches	1 year 9 months 2-3 hours per week
9. Greta (Gr)	July '62	Moderate Cerebral Palsy Right Hemiplegia	1 year 9 months 2-3 hours per week
10. Max (Ma)	August '61	Severe Cerebral Palsy Dystonic Quadriplegia-right side more affected than left Athetosis Dysarthria Wheelchair	2 years 6-9 hours per week
11. Harry (Ha)	August '61	Spinal cord injury Paraplegia Wheelchair	1 year 9 months 2-3 hours per week
12. Stan (St)	July '61	Muscular Dystrophy Wheelchair	1 year 9 months 3-4 hours per week

Appendix 2

Using LOGO Activities to Introduce Basic Concepts of Trigonometry

Ma is an 18 year old boy with severe cerebral palsy of mixed type, enrolled as an 11th grade student in a special school for the handicapped. He has been using Logo for over a year now and has mastered the major LOGO ideas quite well.

In the beginning of his Logo activities, after several sessions exploring some of the LOGO ideas, he initiated a project whose task was to draw the background of Copley Square, a very well known landmark in Boston.

At one point in his drawing he had the church, the Hancock Tower, and intersection with a stop sign. The large street at the intersection represents Boylston Street and the smaller one represents Berkeley Street (see Figure 1.a).

When visitors came to see his work, he would show them this drawing and he found that the picture was not sufficiently representative to be recognized without some hints on his part. At other times the stop sign was even misread as a tree (due, perhaps, to its being out of proportion to the surrounding "buildings".) Ma would sarcastically reply: "a tree in downtown Boston!!" This was a topic for jokes, although Ma was not happy with it. To resolve the problem he proposed that his drawing be labelled with the word "stop" on the stop sig, and the name "Copley Square" written at the top of his drawing (see Figure 1.b).

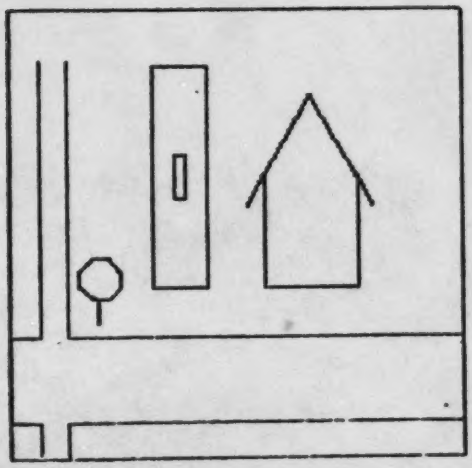


Figure 1a

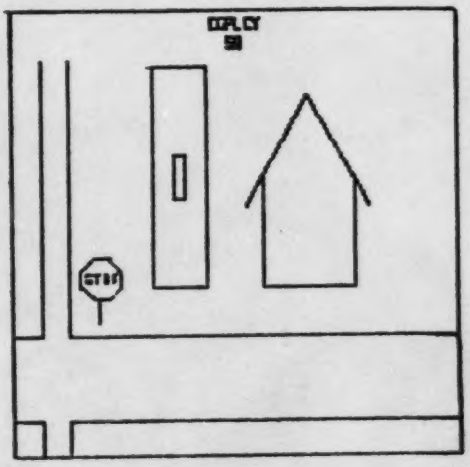


Figure 1b

This new task gave Ma another idea. Since some letters in both words were the same -- eg. O, P, S -- and he needed them in different sizes, why not define procedures to draw the letters used in these two words so it would be possible to change their size? Moreover, why not have procedures like those to draw all the letters of the alphabet? From this point of departure, Ma worked on two projects simultaneously: background of Copley Square and the letters of the alphabet.

To draw letters of the alphabet with variable size, we can imagine each letter being drawn inside an invisible rectangular frame where height and width can be adjusted. If we make all the parts of the letter a function of these two variables, we can change the size of the letter by giving different values to them. Suppose we want to draw the letter G. The rectangular frame is defined as having height Y and width X (fig 2.a). Inside of this frame we can draw the letter G where the parts of it can be defined as shown in figure 2.b

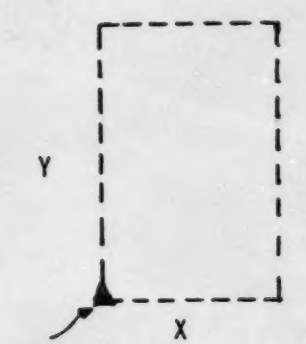


Figure 2a

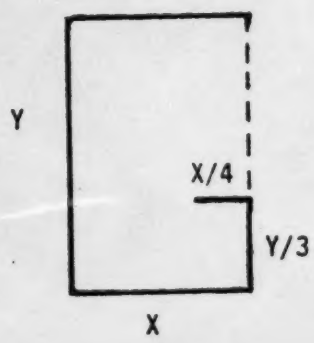


Figure 2b

Figure 2c

```
TO G :X :Y :L
10 PENUP
20 FORWARD :Y
30 RIGHT 90
40 FORWARD :X
50 PENDOWN
60 RIGHT 180
70 FORWARD :X
80 LEFT 90
90 FORWARD :Y
100 LEFT 90
110 FORWARD :X
120 LEFT 90
130 FORWARD :Y / 3
135 LEFT 90
140 PENUP
150 FORWARD :X / 4
160 PENDOWN
170 RIGHT 180
180 FORWARD :X / 4
190 SUP :L :Y / 3
200 HIDETURTLE
END
```

Therefore the procedure to draw the letter G has two variables X and Y (as size of the frame) and a variable L which indicates the distance between two letters. The Logo commands to draw it are shown in figure 2.c.

For those letters which can be drawn using only horizontal and vertical lines -- eg. L, T, E -- it is relatively straightforward to define procedures to draw them. Ma

very rapidly mastered this. However, when the letter has slopes -- eg. R and K -- things are not quite as easy. The angle of the slope and its size change in some relation to the size of the frame. For example:

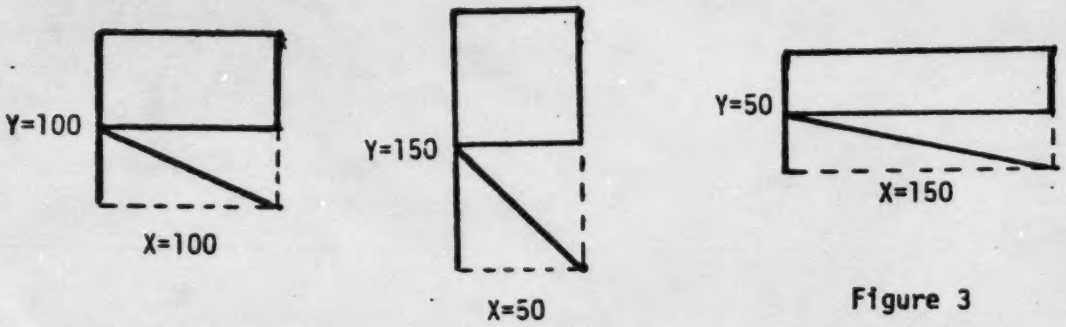


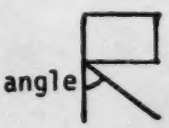
Figure 3

Ma's first attempt was to fix the angle at 45°. He found that this only worked for X=Y. For X not equal to Y we get poor results.

This provided a good chance to introduce Ma to the basic notions of trigonometry or what in the elementary text-books is called practical trigonometry.

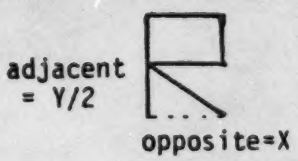
These concepts were presented in the following form.

(a) identify the angle whose value you want to find



(b) define the rectangular triangle that has as one of its angles (different from 90°) the angle you identified in a.

(c) in this triangle identify the sides that are adjacent and opposite to the angle and find their values.



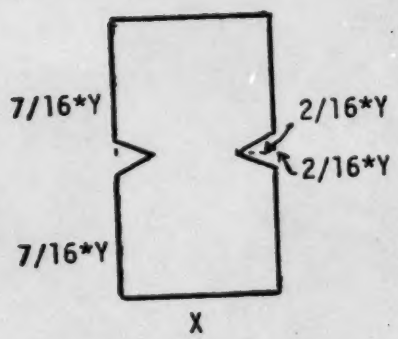
(d) the value of such an angle is give by:

$$\text{ANGLE} = \text{ARCTANGENT} \frac{\text{value of opposite side}}{\text{value of adjacent side}}$$

(e) the length of the biggest side of the triangle (hypotenuse) is given by:

$$Z = \frac{\text{value of adjacent side}}{\cos(\text{ANGLE})}$$

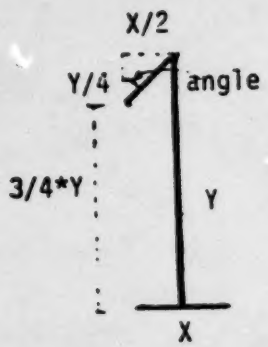
By following this procedure Ma was able to draw all the letters with slopes and show these ideas to his students. He was also able to deal with new details and slightly different problems which he solved in drawing the numbers from 0 to 9. For instance, in the number 8 shown below.




```
TO VIII :X :Y :L
10 FORWARD :Y / 16. * 7.
20 ANG :Y
30 FORWARD :Y / 16. * 7.
40 RIGHT 90
50 FORWARD :X
60 RIGHT 90
70 FORWARD :Y / 16. * 7.
80 ANG :Y
90 FORWARD :Y / 16. * 7.
100 LEFT 90
110 PENDOWN
120 BACK :X
130 PENUP
140 FORWARD :X
150 SUP 0 :L
END
TO ANG :Z
10 MAKE "Z" :Z / 8.
20 MAKE "ANG ARCTAN ( :Z' / ( :Z' / 2. ) )
30 MAKE "H ( :Z' / 2. ) / COS :ANG
40 RIGHT :ANG
50 FORWARD :H
60 LEFT 2 * :ANG
70 FORWARD :H
80 RIGHT :ANG
END
```

Figure 4

These projects also gave Ma some good opportunities to operate algebraic expressions and fractions, and the more sophisticated syntax of these more powerful Logo procedures (for example, in drawing the number '1').




```
TO I. :X :Y :L
10 PENUP
20 FORWARD :Y / 4. * 3.
30 MAKE "ANG ARCTAN ( ( :X / 2. ) / ( :Y / 4. ) ) *
40 PENDOWN
45 RIGHT :ANG
50 FORWARD ( :Y / 4. ) / COS :ANG
70 RIGHT 180 - :ANG
80 FORWARD :Y
90 LEFT 90
100 PENUP
110 BACK :X / 2.
120 PENDOWN
130 FORWARD :X
140 SUP 0 :L
END
```

Figure 5

Appendix 3

Cotting School for Handicapped Children

241 St. Botolph St., Boston, Mass. 02115 — Phone (617) 536-9632

(Formerly Industrial School for Crippled Children)

March 12, 1979.

Sylvia Weir, M.D.
M.I.T. Logo Lab
545 Tech Square
Cambridge, Massachusetts 02139

Dear Doctor Weir:

I would like to share with you some of our observations of the many positive results of Project Logo and its impact on our student body to date.

First of all, we are just delighted by the deep concern that you, Jose and Gary show toward our students in general, and toward Ma in particular. I am certain that this has had a direct bearing upon the project, and upon the growing interest among our other students to become involved in the computer project.

One of the most important spin-offs has been the demonstration by Ma that confirms our longtime suspicion that he did possess average, or better, intelligence. As you know, Ma's serious speech problem prevented his participation in classroom discussions and verbal testing. Ma's athetoid movements prohibited him from other forms of testing, writing and manipulative exercises. We could only assume, as a result of our observations, that he did possess normal intellectual capacities.

Now, however, we have demonstrated evidence that rather proves that we have been underestimating him.

Up until now, Ma has been the quiet kid in the electric wheelchair that "was there." He demonstrated no leadership qualities.

Since Project Logo, we have seen a remarkable change in Ma. With the development of these new skills, Ma is now "somebody!" He is doing something that no other student (at this school) is doing. He is, for the first time in his life, "top dog!" He has developed a wonderful sense of self-worth, and his personality has improved remarkably. He now has a more positive attitude, has developed poise and shows more confidence in his ability to contribute.

cont'd.....

William J. Carmichael, Superintendent

Sylvia Weir, M.D. March 12, 1979.

We cannot yet prove it, but we have a very strong suspicion that his gross and fine motor movements have improved. There is a smoothness in his moves, especially around the keyboard, that was not present at the outset of this project.

Ma did not have Math training beyond basic Algebra before starting this project. He has learned much in Geometry in the process of programming and using the computer, and he has developed an organized way of thinking.

Beyond this, he has taken the initiative to call Jose by telephone when the computer breaks down. This requires someone to dial the number for him, and then he's on his own.

We are requesting a push button phone so that he can dial for himself.

Ma now has several groups of students that he is teaching on the computer, and in his own words, he is learning more by answering their questions of, "Why?"

We are quite excited at the staff level, because this experience has highlighted the need for this school to become computer-oriented.

The "bottom line" on all of this is a vocational placement. That is the purpose of the school, and Project Logo has opened up a new avenue for us to explore when planning for our more severly handicapped students.

I do not want to sound too "syrupy", but we are just elated by what has happened so far - and we can't wait for the next chapter.

Sincerely,

William J. Carmichael
Superintendent

wjc/p